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How Gamification Applies for Educational Purpose Specially with College Algebra

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Abstract

Gaming environments have been used to teach mathematical topics such as addition and division in a fun manner[*]. However, when it comes to college level mathematical concepts such as the use of the quadratic formula, there are very few software that explain these concepts in a fun way. In this paper, we present a first step towards using video game elements and Artificial Intelligence Tutoring system techniques to teach mathematical concepts such as factoring and the quadratic formula. These concepts are explained in a way that helps learners make a connection between the mathematical concepts and their real life experience. These methods of learning are supported by several studies (Bonwell & Eison, 1991; Donovan & Bransford, 2004; Scarlatos, 2006). We use gamification techniques during the training and test phases to help students learn the mathematical concepts. We then compare the performance of students who used our system (MathDungeon) with that of students who used the most popular math tutoring programs used in US colleges: Assessment and Learning, K-12, Higher Education (ALEKS). The number of students who used MathDungeon and scored above the median score on the test of math performance was greater than the number of students who used ALEKS and scored higher than the median score.

Keywords: Gamification, Artificial Intelligence, Tutoring systems, How to gamify mathematics' concepts

1 Introduction

Many people struggle when it comes to learning mathematics. Scientists and teachers all around the world suggest different methods to learn mathematics[†] (Melis & Siekmann, 2004; Stanislav, 2013).However, teachers cannot individualize courses for every student in a classroom separately,

[*] http://www.thefreedictionary.com/fun
[†] www.carnegielearning.com

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despite the fact that students have different levels of mastery and require different levels of assistance,. With the emergence of intelligent tutoring systems (ITS) and gaming technologies[‡], more domain-specific and individualized lessons have been created, for topics such as math[§] (Anderson, 1992; Bonwell & Eison, 1991; Corbett, Koedinger, & Anderson, 1997; Latham, 2012; Melis & Siekmann, 2004) or teaching astronauts how to manipulate Canadian Arm, which is installed on the International Space Station (Faghihi, Fournier-Viger, & Nkambou, 2012). To achieve individualized lessons, an essential step is creating adaptive systems (Melis & Siekmann, 2004). That is, during a training session, the system must adapt to the user's needs by generating an individualized course on the fly. To do so, ITSs use different tools and techniques, such as scaffolding. That is, offering extra hints and information to the user in order to reduce the learning curve. One important goal of ITS is to maintain learners'motivation during the training sessions. Many psychological methods such as instructionalist and constructivist are used to engage students and motivate them during training sessions (D'Mello, Lehman, & Graesser, 2011; Insights, 2011).

Using ITS tools, many tutoring systems have been created to teach mathematics and other skills at the college level. Although AI techniques have shown success in helping learners learn different topics, a component of fun in the learning process is missing in these environments, where they would be essential to deal with difficult math concepts. One might ask, what shall we do if you are teaching math and your students aren't into it?

However, making simple, fun and easy game environments that can represent various college level mathematical concepts is cumbersome. To make a learning session fun, engaging and easy, we can use gamification (Kapp, 2012; Nicholson, 2012; Zichermann & Cunningham, 2011) and ITSs techniques such as: 1) Competition and feedback: Players constantly know where they stand and where everyone else stands. They also receive hints and are prompted about their progress towards short-term and long-term goals. A slight difference between gaming environment (GE) and ITS for feedback is that ITS uses messages such as hints to motivate, and confirm learners' actions. However, GE uses rewarding strategies such as badges; 2) Badges: once a player achieves a goal, it is clearly shown together with the score on the main menu of the application; 3) Leveling up: as players are done with a task, the game promotes them to higher levels.

The goal of this paper is to use ITS tools, gaming technology, as well as artistic animations, to create college level mathematics lessons that are fun, combining play with learning. In section two, we briefly discuss gaming environments that were conceived for learning mathematics. In section three, we describe our system (MathDungeon), which is conceived to teach mathematics concepts at the college level. We then show that by adding fun to learning sessions, the students retain mathematics concepts for a longer period of time (see section 4). We show that the number of students who used MathDungeon and scored above the median performance score was higher than the number of students who used ALEKS[**] and scored higher than the median score.

2 Related works

"Tell me and I forget, teach me and I may remember, involve me and I learn."
— Benjamin Franklin

Nowadays, game technology and gamification surround our daily life (McCallum, 2012). Games are created as hobbies for children and adults. Governments use them to encourage people to pay their

[‡] http://www.mangahigh.com/en_us/
[§] http://www.fun4thebrain.com/
[**] http://www.aleks.com/., http://www.mangahigh.com/en-us/., http://www.mathplayground.com/., http://matematika.hrou.cz/., http://www.ixl.com/., https://www.khanacademy.org/., http://www.mangahigh.com/., http://www.coolmath.com/., http://www.onlinemathlearning.com/

taxes and use public transportation (MacDonald, 2012; Newsom & Dickey, 2013; Zichermann & Cunningham, 2011). Many researchers and companies have been working on the learning of math using game technology, namely, Goodwin for middle grade math games[††]. Among others, gaming environments such as math playground, are shown to be useful for children learning math skills (Stanislav, 2013). However, math playground lacks tutoring elements. Khan Academy covers mathematics, among other topics, but ITS (i.e., hints) and gamification elements (i.e., badges), are missing (Scarlatos, 2006). That is, the fun part of the lessons and learning are absent on this website.

Some of the aforementioned gaming environments also lack scaffolding for learners or they are not fun at all. Given that a quadratic formula can be solved in different ways (see next section for more details), a gaming environment that claims to use gaming elements must let learners select the way they want to learn and solve problems. In addition, a learning gaming environment needs to define constraints to guide learners towards achieving their goals. These constraints need to be meaningful to the learners and meet the goal of the learning environments.

However, when a math concept is gamified, the gaming environment needs to help learners make associations between the gaming elements, aspects of the non-game activities, *the learners' own goals and the learners' own desires (Nicholson, 2012)*.To our knowledge, for higher- level mathematical concepts (i.e., quadratic formula such as), gaming environments have failed to make learning and practicing mathematical concepts fun for students. This is in part because the current ITS lacks the artistic animation tools that can help designing fun lessons and fun interactions. Therefore, to design and implement the MathDungeon environment, we followed these major steps:

1) For each specific concept, we identified possible solutions and various ways that the necessary concepts could be taught.

2) For each concept and lesson, we designed corresponding gaming environments and elements in real games (i.e., cubes that explode Figure 3).

3) For each concept, the lessons and solutions were discussed from an artistic point of view: artistic and real life examples were used to make the lesson concepts fun;

4) The psychological component of the lesson were considered: we found real life entities that can be associated with every math concept and lesson.

5) We integrated the gaming environment and ITS tools, which are mentioned above (all but the conversational feature) into MathDungeon;

6) We designed the environments in such a way that allow learners to choose how to learn and solve problems in the game;

7) We integrated gamification tools such as badges and scoring;

8) We integrated ITSs' tools such as scaffolding into the MathDungeon.

In the next section we describe the MathDungeon game.

3 MathDungeon[‡‡] Description

Given that this paper focuses on the first step of to the process for gamifying upper-level mathematical concepts, in this section, we describe the MathDungeon's tutoring tools briefly.

For every math concept, there can be various solutions and various ways to provide explanations. For instance, a quadratic formula can be solved, among others, by factoring, completing the square, and graphing. Furthermore, in our experience, the way an art student prefers to learn the quadratic formula (Figure 1.B) is different from that of a math student (Figure 1.C). MathDungeon individualizes the concepts and exercises according to the learners' preferences and offers a variety of choices: either for the training sessions or for the problem solving sessions. For instance, when a

[††] http://www.aleks.com/., http://www.mangahigh.com/en-us/., http://www.mathplayground.com/., http://matematika.hrou.cz/., http://www.ixl.com/., https://www.khanacademy.org/., http://www.mangahigh.com/., http://www.coolmath.com/., http://www.onlinemathlearning.com/

[‡‡] http://cs.sulross.edu/ . Need permission to be able to download the software.

learner selects a goal (i.e., a quadratic lesson, Figure 1), the session manager sends a request to the course generator to find out how many lessons and problems can be offered for that specific concept. The course generator queries mathematical knowledge modules to select the content to be learned. In order to find out the users' prior knowledge and preferences, the course generator also needs to query the student model. MathDungeon, in addition to including tutoring elements such as hints and feedback for each specific concept, also offers different levels of difficulty and gaming environments to match the various lessons and exercises (Figure 1). The different levels for each mathematical conceptare designed to be intuitive, in such a way that they will not cause any confusion to the learners.

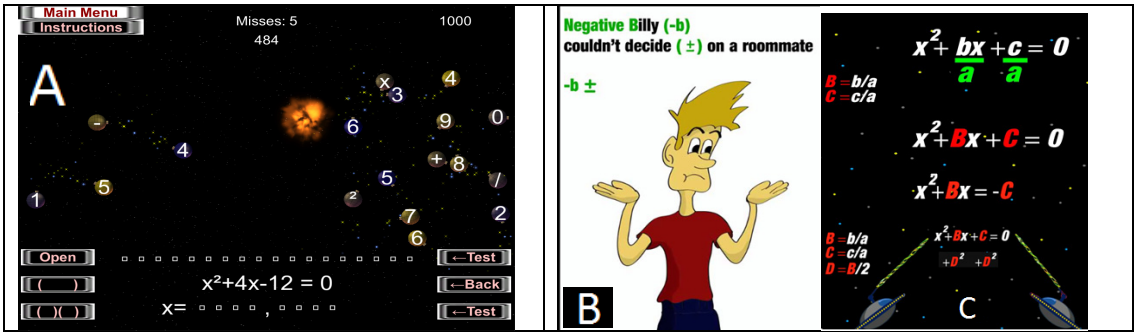

Figure 1.A Factoring a quadratic formula.F 1.B,C are the explanations of the quadratic formula for learning

To understand what the learner is doing continuously, we made a parser for the learners' activities. Accordingly, the system can decide to assign a score, give hints, presentation, change some specific fonts, play an audio file, blink buttons or level up. Time for solving problems is very important. Because each problem requires that it be solved in a specific time frame, the timing to solve each problem is decided according to the average time learners spend solving problems. However, the system also adapts to the learners' pace by providing more or less time, as needed.

In MathDungeon, a learner can start each level with one or more animations (Figure 1.B,C) that teach a lesson about, for example, the quadratic formula: Players are free to follow the lesson, which is a fun animation, or start playing (Figure 1.A) with the game and solve the problems. One important difference between MathDungeon and other existing systems (Anderson, 1992; Bonwell & Eison, 1991; Corbett et al., 1997; Latham, 2012; Melis & Siekmann, 2004) is that we make parallels with real life to explain mathematical concepts. For instance, to teach the quadratic formula, our system proposes the following lesson. Instead of saying –b, the animation says negative Billy (-b) (Figure 2, left) who could not decide (±) on a roommate, decided to room with radical Bobby instead of living on the second floor (2) with Andrew (a) (Figure 1.B). Important to note, the learner may also select a purely mathematical lesson (Figure 1.C).

To make sure that the learner has learned a lesson, he or she will be asked to start a practice session (Figure 1.A). While practicing in the game mode, if the user forgets any part of the quadratic formula, a hint with a picture and spoken message that, for instance, says "Do you remember with whom negative Billy decided to room?" will be presented to the learners. Once the practice session is over, the learner is asked to re-create the entire quadratic formula step-by-step by themselves- this constitutes the evaluation and scoring phase.

4 Experiments

We selected 30 students at Sul Ross State University (SRSU), and divided them into three groups, 1) the MathDungeon group (n=10), 2) the ALEKS group (n=10) and 3) a comparison group which received no tutoring help (n=10).

Students were tested with a quiz for mathematical abilities prior to the tutoring session and post tutoring session. The quizzes were regular classroom quizzes. Students were given a Quiz of 20 questions pertaining to the quadratic formula and factoring. The questions were different pre and post-test, but of the same level of difficulty. We obtained change from baseline scores by subtracting the pre-tutoring performance of each student to his or her performance post-tutoring procedure. Running a median test, we found that there are a greater number of students scoring above the median score in the group having played MathDungeon than in the group having used ALEKS or in the comparison group. Indeed, 6 out of 9 students in the SRSU MathDungeon group scored above the median, whereas only 2 out of 8 students in the ALEKS group scored above the median. (See graph 1, Left panel).

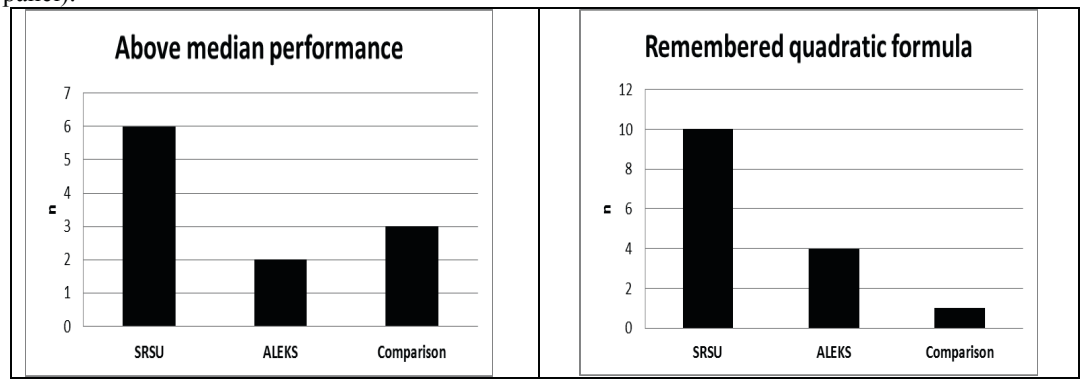

Table 1 Graph 1-a) Left panel, the number of students in each condition who scored above the median score on a post-tutoring test of mathematical performance (solving the quadratic formula). - b) Right panel, the number of students in each condition who remembered the full quadratic formula.

Furthermore, we found that students who remembered the quadratic formula were those who had played MathDungeon. Comparing who remembered the entire quadratic formula 10 days following the procedure, we found that 10 students in the MathDungeon group remembered the formula, compared to only 4 of the students in the ALEKS group, and only 1 in the comparison group.

It must be noted that although we gave the learners the choice to select their preferred method of learning (i.e., Figure 1.B,C), only one learner selected purely mathematical explanations (Figure 1.C). That is why we did not made comparison with the math-only group.

5 Conclusion

Video games can use Intelligent Tutoring systems (ITS) and gamification tools to foster learners' confidence. They are also able to present various approaches to solve a given problem. Although many gaming environments exist to teach mathematics to children, no such game exists for college level math. Using ITS and gaming tools to design and implement a tutoring system that explains, for instance, the quadratic formula, is not an easy task. One important part in the design of such a system is to consider the fun part of the system as well as giving the learners the choice of how to learn and deal with the problems. The fun part of our system is implemented in the following manner: 1) background music which can be turned on or off; 2) each interaction with objects in the environment

is followed by a sound, audio, or a message such as hints or a primitive text to speech sound; 3) to explain the concepts and make learners laugh, real life examples are used; 4) surprise events occur in the game and are linked to the learners' activities. For instance when a learner selects an incorrect answer (i.e, wrong cube), it can explode or bounce around (see Figure 2 right side); 5) the learner is free to choose the type of lesson s/he prefers and how to solve a problem.

In this paper, we showed a first step towards making a new generation tutoring system that is able to bring college level math into the gaming industry. One future step would be to add a conversational agent such as AutoTutor Lite§§ to our system MathDungeon. Our proof-of-principle results are promising and demonstrate that this idea is worth pursuing. In the future, it would be useful to to compare users who used MathDungeon and ITSs' system such as AutoTuror Lite in a larger sample of participants.

References

Anderson, J. R. (1992). *Intelligent tutoring and high school mathematics.* Paper presented at the Intelligent tutoring systems.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom*: School of Education and Human Development, George Washington University Washington, DC.

Corbett, A. T., Koedinger, K. R., & Anderson, J. R. (1997). Intelligent tutoring systems. *Handbook of humancomputer interaction*, 849-874.

D'Mello, S. K., Lehman, B., & Graesser, A. (2011). A motivationally supportive affect-sensitive autotutor *New Perspectives on Affect and Learning Technologies* (pp. 113-126): Springer.

Donovan, M. S., & Bransford, J. D. (2004). *How students learn: History in the classroom*: National Academies Press.

Faghihi, U., Fournier-Viger, P., & Nkambou, R. (2012). CELTS: A Cognitive Tutoring Agent with Human-Like Learning Capabilities and Emotions. In L. C. Jain, R. J. Howlett & T. Ditzinger (Eds.), *Smart Innovation, Systems and Technologies*: 2190-3018 http://www.springer.com/series/8767.

Insights, M. M. (2011). K–12 Education: Opportunities and Strategies for Ontario Entrepreneurs.

Kapp, K. M. (2012). *The gamification of learning and instruction: game-based methods and strategies for training and education*: Wiley. com.

Latham, A. (2012). A conversational intelligent tutoring system to automatically predict learning styles.

MacDonald, A. (2012). Can We Change Behaviour and Meet Objectives Through Fun. *Ottawa: Policy Horizons Canada*.

McCallum, S. (2012). Gamification and serious games for personalized health. *Stud Health Technol Inform, 177*, 85-96.

Melis, E., & Siekmann, J. (2004). Activemath: An intelligent tutoring system for mathematics *Artificial Intelligence and Soft Computing-ICAISC 2004* (pp. 91-101): Springer.

Newsom, G., & Dickey, L. (2013). *Citizenville: How to Take the Town Square Digital and Reinvent Government*: Penguin. com.

Nicholson, S. (2012). A user-centered theoretical framework for meaningful gamification. *Proceedings GLS, 8*.

Scarlatos, L. L. (2006). Tangible math. *Interactive Technology and Smart Education, 3*(4), 293-309.

Stanislav, V. (2013). Online Problems for Mathematics and Computer Science Education.

Zichermann, G., & Cunningham, C. (2011). *Gamification by Design: Implementing game mechanics in web and mobile apps*: O'Reilly Media, Inc.

§§ http://www.skoonline.org/home